Advanced analysis and classification of glioblastoma optical spectra using Machine Learning and Deep Learning

Scientific Context

Gliomas represent the most prevalent form of central nervous system tumors. These tumors are characterized by their infiltrative nature, comprising both a solid tumoral component and an infiltrative component that poses significant challenges in differentiation. The primary therapeutic approach for gliomas revolves around maximal feasible resection. However, during surgical interventions, the decision to continue or cease resection entails a delicate balance between eradicating as many tumor cells as possible and safeguarding vital functional brain regions. Currently, the gold standard for assessing tumor tissue type (tumor or healthy) relies on anatomopathological measurements, involving the extraction of a biopsy from the brain. Although highly accurate, this procedure is time-consuming. Hence, there is an urgent need for expedited intraoperative insights into biopsy analysis.

A complementary approach leverages intraoperative 5-ALA PpIX (5-Aminolevulinic acid-induced protoporphyrin IX) fluorescence imaging, which has demonstrated improvements in the resection process. However, it still grapples with sensitivity issues. Previous studies and preliminary findings have unveiled the intricacies of the PpIX fluorescence spectrum, far surpassing the conventional understanding in the literature. This spectral complexity harbors invaluable and complementary information for precise tumor margin delineation during resection. Further delving into this spectral complexity is imperative, exploring diverse hypotheses to affirm the existence of two closely situated emission spectra, one peaking at 620 nm and the other at 634 nm, within the biopsy [1,2].

In tandem with this research, the HyperProbe project [3] is currently underway, embarking on the development of a groundbreaking optical imaging device designed to elevate brain surgery. This innovative technology is poised to significantly enhance patient treatment outcomes and life expectancy by empowering neurosurgeons with advanced real-time guidance and information during surgical procedures.

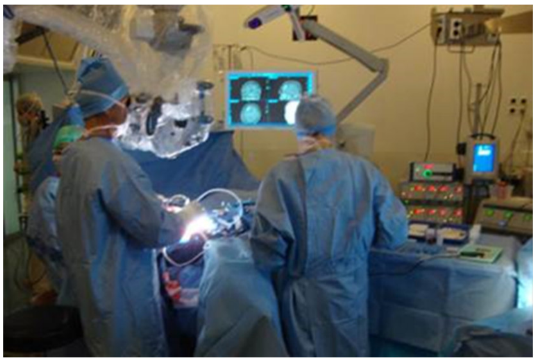
Internship Objective

The primary goal of this internship is to advance the field by developing and applying machine learning and deep learning models for the in-depth analysis and classification of optical spectra derived from glioblastoma tissues, incorporating new data and those generated by the HyperProbe device. The following key tasks will be addressed:

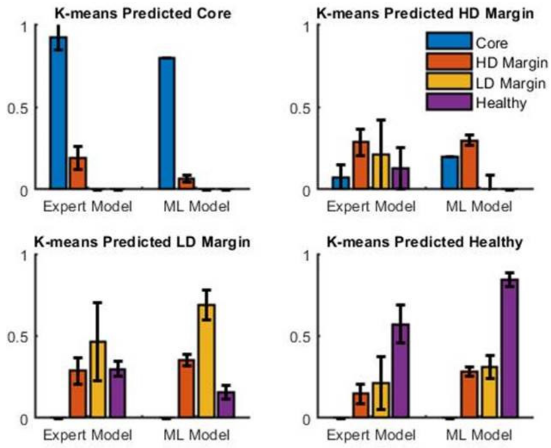
1. Data Preprocessing: Curating, cleansing, and standardizing optical spectra to ensure their readiness for analytical purposes.
2. Feature Extraction: Pioneering techniques for extracting pivotal features from intricate optical spectra.
3. Classification: Crafting high-precision classification models capable of distinguishing between various glioblastoma types and identifying specific signatures associated with treatment response.
4. Interpretation of Results: Scrutinizing and elucidating the insights garnered from developed models to elucidate essential facets of glioblastoma biology and the potential identification of targets for more efficacious treatments.

Methodology

This internship will encompass the utilization of machine learning libraries (e.g., scikit-learn) and, potentially, deep learning methodologies to construct and rigorously assess these models. Advanced techniques such as Convolutional Neural Networks (CNNs) and deep neural networks will be explored to effectively extract relevant information from the intricate optical spectra. The dataset utilized will be sourced from reputable medical databases and adhere to stringent ethical and confidentiality standards.



In vivo experiment during surgery



“Machine Learning model” vs “Expert model” results

Expected Outcomes

Upon the culmination of this internship, the intern is expected to have developed sophisticated machine learning and deep learning models for the analysis and classification of glioblastoma optical spectra, including data acquired through the HyperProbe project. These results are anticipated to significantly enrich our comprehension of glioblastoma biology, provide profound insights into the spectral intricacies of PpIX fluorescence, and establish a robust foundation for the identification of potential enhancements in intraoperative biopsy analysis.

Conclusion

This internship presents an extraordinary opportunity to apply cutting-edge data science techniques in the pursuit of resolving critical challenges in glioblastoma surgery and tumor characterization. It promises to contribute to the advancement of oncology research while endowing the intern with invaluable skills in data processing, machine learning, and deep learning.

Candidate Profile

We are actively seeking candidates with a strong educational background in computer science, data science, or related fields, encompassing both master's and engineering students. Proficiency in Python is highly desirable, and prior knowledge of pertinent libraries and frameworks for machine learning and deep learning (e.g., scikit-learn, TensorFlow, or PyTorch) is an advantage. Candidates should also exhibit a passionate interest in medical imaging, oncology, and the application of data science to address real-world healthcare challenges. Strong problem-solving abilities, a capacity to work autonomously and collaboratively, as well as excellent communication skills, are vital prerequisites.

Contacts

Cédric RAY-GARREAU cedric.ray@univ-lyon1.fr, Bruno MONTCEL bruno.montcel@univ-lyon1.fr
CREATIS https://www.creatis.insa-lyon.fr/

References

1. B. Montcel, L. Mahieu-Williame, X. Armoiry, D. Meyronet, and J. Guyotat, “Two-peaked 5-ALA-induced PpIX fluorescence emission spectrum distinguishes glioblastomas from low-grade gliomas and the infiltrative component of glioblastomas,” Biomedical Optics Express 4, 548 (2013). (https://doi.org/10.1364/BOE.4.000548).

2. A. Gautheron, M. Sdika, M. Hébert, and B. Montcel, “An explicit Estimated Baseline Model for Robust Estimation of Fluorophores using Multiple-Wavelength Excitation Fluorescence Spectroscopy," IEEE Transactions on Biomedical Engineering (2023). (https://doi.org/10.1109/TBME.2023.3299689).
3. The HyperProbe project receives funding from the European Union’s Horizon Europe research and innovation program under grant agreement No 101071040. (https://hyperprobe.eu/).
4. P. Leclerc, C. Ray, L. Mahieu-Williame et al. “Machine learning-based prediction of glioma margin from 5-ALA induced PpIX fluorescence spectroscopy”. Sci Rep 10, 1462 (2020). (https://doi.org/10.1038/s41598-020-58299-7).